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Stabilization of Shallow Slope failure on Expansive Clay using Recycled Plastic Pin

Recycled Plastic Pin (RPP)
- Mainly Polymeric Materials
- Fabricated from Recycled Plastics

Advantages
- Commercially Available
- Use of RPP Reduces Waste Volume
- Resistant to Biological Exposure

Typical Composition
- HDPE : 55-90%
- LDPE : 5-10%
- PP, PET, PS : 1% - 10%
- Misc. : 0 – 5%

A 10' long RPP can replace 500 Soda Bottles
**Factor of Safety:**
Without Reinforcement
\[ FS = \frac{Mr}{Md} \]

**Factor of Safety:**
With Reinforcement
\[ FS = \frac{(Mr+\Delta Mr)}{Md} \]

**Legend:**
- **Red:** Clay having high swelling potential
- **Blue:** Less than 50% of clay contents having high swelling potential
- **Orange:** Clay content having slight to moderate swelling potential
- **Green:** Less than 50% of clay contents having slight to moderate swelling potential
- **Brown:** Little or no swelling clay
- **Yellow:** Insufficient data
Most Slope Failure in Texas takes place due to the Shrink Swell behavior of Expansive Clay and Formation of Perched Water Zone due to Rainfall

Site Selection

Expansive Clay
Site Investigation: US 287 Slope

Bore Hole Location | Depth of Sample | Liquid Limit | Plasticity Index
BH-1              | 5              | 48           | 25
BH-1              | 10             | 60           | 33
BH-1              | 15             | 72           | 48
BH-1              | 20             | 64           | 38
BH-2              | 5              | 49           | 26
BH-2              | 10             | 67           | 38
BH-2              | 15             | 73           | 45
BH-2              | 20             | 61           | 35
BH-2              | 25             | 62           | 37
BH-3              | 5              | 52           | 27
BH-3              | 10             | 61           | 34
BH-3              | 15             | 79           | 51
BH-3              | 20             | 58           | 32
BH-3              | 25             | 62           | 40
Site Investigation: Resistivity Imaging

Resistivity Profile: RI-1

Resistivity Profile: RI-1

Comparison of Soil Boring and RI

Moisture Variation along the borehole

Variation of Resistivity
Failure Investigation: Back Analysis

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Friction Angle</th>
<th>Cohesion</th>
<th>Unit Weight</th>
<th>Elastic Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>φ</td>
<td>c</td>
<td>ϒ</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>100</td>
<td>125</td>
<td>100000</td>
</tr>
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<td>25</td>
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<tr>
<td>4</td>
<td>35</td>
<td>3000</td>
<td>140</td>
<td>250000</td>
</tr>
</tbody>
</table>

Failure Investigation

- Shoulder Cracks
- Slope Failure Initiation Zone
- Slip Surface 1
- Slip Surface 2
- Slip Surface 3
- Rain Water Intrusion
- Pavement
- Rainfall

Soil Type: 1, 2, 3, 4
Friction Angle: φ
Cohesion: c
Unit Weight: ϒ
Elastic Modulus: E
RPP Layout

Reinforced Section 1

Reinforced Section 2

Reinforced Section 3
Design of Slope Stabilization

Back Analysis of Unreinforced Slope: FS = 1.05

Reinforced Section 1: FS = 1.43
Reinforced Section 2: FS = 1.48
Reinforced Section 3: FS = 1.54

Back Calculated Soil Parameters

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Friction Angle</th>
<th>Cohesion</th>
<th>Unit Weight</th>
<th>Elastic Modulus</th>
</tr>
</thead>
<tbody>
<tr>
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<td>3000</td>
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</tr>
</tbody>
</table>

Installation of RPP: Reinforced Section 1 and Reinforced Section 2

- Equipment: Klemm 802 Drill Rig
- Hammer Type: KD 1101
Installation of RPP:

Installation of RPP: Reinforced Section 3
### Installation Details

<table>
<thead>
<tr>
<th>Section</th>
<th>No. of RPP</th>
<th>Installation Time(Day)</th>
<th>Start Date</th>
<th>Finished Date</th>
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</thead>
<tbody>
<tr>
<td>Reinforced Section 1</td>
<td>192</td>
<td>2</td>
<td>March 01, 2011</td>
<td>March 03, 2011</td>
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<td>Reinforced Section 2</td>
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<td>March 04, 2011</td>
<td>March 05, 2011</td>
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<td>Reinforced Section 3</td>
<td>238</td>
<td>3</td>
<td>Feb 29, 2012</td>
<td>March 06, 2012</td>
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</table>

### Instrumentation

- Rain Gauge
- Instrumented RPP
- Surveying
- Inclinometer
- Moisture Sensor
- Water Potential Probe
Instrumentation: Instrumented RPP

- 10 ft RPP @ 3 ft/c
- 10 ft RPP @ 6 ft/c
- 8 ft RPP @ 6 ft/c
- 8 ft RPP @ 5 ft/c
- 10 ft RPP @ 4 ft/c
- 10 ft RPP @ 4 ft/c
- 8 ft RPP @ 4 ft/c
- 10 ft RPP @ 4 ft/c

Instrumentation: Instrumented RPP

10 Plastic Pin

Data Acquisition System
Instrumentation: Inclinometer

Instrumentation: Surveying
Comparison of Strain: Reinforced Section 1, Control Section and Reinforced Section 2

- Rainfall
- IM-3 @ 2ft
- IM-5 @ 2ft
- IM-8 @ 2ft

Total Settlement at the crest of US 287 slope

- 5.6.12
- 6.6.12
- 7.13.12
- 9.8.12
- 10.6.12
- 11.10.12

- 1.10.13
- 2.9.13
- 3.7.13
- 4.5.13
- 5.20.13
- 7.1.13
- 8.2.13
Results: Surveying

Incremental Settlement of at Crest of the Slope

- 8.3.12
- 1.10.13
- 4.5.13
- 5.20.13
- 8.2.13

Site Condition

R. Section 1

Control Section 2

Control Section

R. Section 3
Results: Inclinometer

Horizontal Displacement with time at Inclinometer 1

- Rainfall
- 2.5 ft-Inc 1
- 6.5 ft-Inc 1
- 10.5 ft-Inc 1
- 20.5 ft-Inc 1

Results: Inclinometer

Horizontal Displacement with time at Inclinometer 3

- Rainfall
- 2.5 ft-Inc 3
- 6.5 ft-Inc 3
- 10.5 ft-Inc 3
- 20.5 ft-Inc 3

Date

Displacement (inch)

Rainfall (inch)
Comparison of Displacement

Comparison of Horizontal Movement at US 287 Slope

- Rainfall
- 2.5 ft-Inc 1
- 2.5 ft-Inc 3

Comparison between Rainfall, Moisture Content, Matric Suction and Horizontal Displacement

- Rainfall
- M/C
- Matric Suction
- Displacement
Comparison between Rainfall, Moisture Content, Matric Suction and Horizontal Displacement

Comparison with Temperature and Shrinkage Cracks
Comparison of Slip Surface

Comparison Between US 287 Slope and I-435 Site at Kansas City, Missouri
Comparison between North Bound and South Bound (Reinforced) Slope

North Bound Slope: Failure Location 1
RPP provided resistance against shallow slope failure

A Crawler-Mounted Rig, Equipped with a Mast-Mounted Pseudo Vibratory Hammer, Worked Effectively to Install RPPs

On Average, a RPP Can be Installed within 4 Minutes, and a Total of 100 to 120 RPPs can be Installed in a Single Day.

Settlement at Control Section is 15 inch

Settlement at Reinforced Section 1 is 2.5 inch.

Closer RPP Spacing at Crest Provided Higher Resistance against Slope Deformation

Only 15% to 16% of the Total Capacity of RPP is Currently Mobilized

RPP can save the stabilization cost up to 60% - 80% of conventional technique, and have potential to be an effective sustainable alternative to stabilize shallow slope failure.
Thank You